U. S. DEPARTMENT OF AGRICULTURE

FARMERS' BULLETIN No. 1599

SCAB OF WHEAT AND BARLEY *and its control*

A 90-acre field of Marquis wheat ruined by scab

SCAB greatly reduces yields, lowers quality, and lessens feeding value.

The disease occurs in the Central States and eastward on wheat, barley, rye, oats, and corn.

The scabbed heads soon bleach to a straw color and are conspicuous before the grain ripens. The scabbed kernels are shriveled, rough, and scabby, and frequently are covered by a grayish-white to carmine-red mass of the fungus mycelium and spores.

When scabbed kernels are used for seed, the parasite causes poor germination and the blighting and weakening of seedlings.

The scab parasite grows on old cornstalks, straw, and crop refuse during the winter and forms spores *on this crop refuse, especially cornstalks. These* spores are blown to the flowering grain the next season.

Moist, warm weather during and following the flowering period favors the development of scab.

To control the disease—

(1) Plow under old cornstalks completely and clean up crop refuse. Do not sow grain among cornstalks.

(2) Use cleaned and treated seed.

(3) Use adapted and scab-resistant varieties.

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SCAB OF WHEAT AND BARLEY AND ITS CONTROL

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INTRODUCTION

SCAB, or Fusarium blight, is a disease of wheat, barley, rye, and oats caused chiefly by a minute fungous parasite known by the Latin name *Gibberella saubinetii* (Mont.) Sacc. In 1919 it was estimated that losses of spring and winter wheat alone, caused by this disease, amounted to about 80,000,000 bushels. In 1928 the disease was destructive again, particularly to spring wheat and spring barley.

The disease attacks not only the heads of small grains but also the seedlings. It attacks the seedlings of corn and also the stalks and ears. The fungus lives over winter abundantly in diseased cornstalks and also on old diseased straw and stubble or small grains.

Losses from scab on small grains depend chiefly on (1) relative abundance of the fungous parasite on old crop refuse, such as cornstalks, straw, and stubble, in the fields, and (2) weather conditions during or shortly after the blossoming period of the grain.

The disease appears during humid summers on barley, wheat, rye, and oats sown on poorly prepared cornland or wheatland. Where severe losses from scab have occurred, they have always been associated with fields where cornstalks, wheat straw, or similar crop refuse had been left partly turned under or on the surface of the field. For example, during 1928 the barley growers in southern Wisconsin who sowed barley on poorly plowed cornland suffered an average loss of about 17 per cent of their crop. In contrast, the farmers who sowed barley on cornland from which the corn was removed and the stubble completely plowed under sustained less than 2 per cent loss from scab. In other words, care in preparing the soil alone netted these growers a saving of 15 per cent of their crop. In fact, the scab

disease was destructive in Wisconsin during 1928 only where barley or wheat was sown on poorly plowed or disked cornland. In Iowa, Illinois, and Indiana the saving by sowing small grains on clean land was even greater, frequently meaning the difference between success and failure, especially with barley. The scab disease and the European corn borer are both most effectually controlled by the complete plowing under of cornstalks.

OCCURRENCE OF THE DISEASE

The disease occurs throughout the world wherever wheat is grown, except in dry regions. In the United States it occurs in greater or less abundance each year from the Mississippi Valley eastward. During wet seasons the disease may extend westward into Kansas, Nebraska, and the Dakotas. During the season of 1928 scab occurred

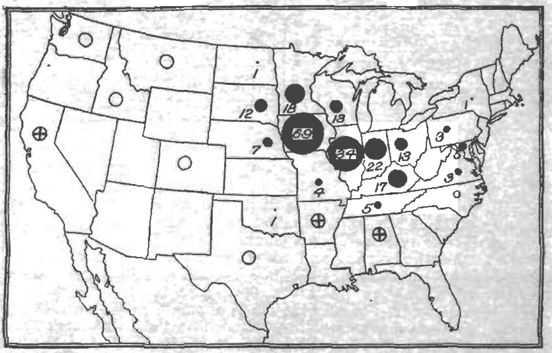

FIGURE 1.—Outline map of the United States, showing estimated percentages of all wheat infected with scab in 1919. The numerals and comparative size of the black circles represent the average percentage of infection: ⊕ = trace; ○ = surveyed but no scab found. Data obtained by the Offices of Cereal Crops and Diseases and of Mycology and Disease Survey of the Bureau of Plant Industry

in epidemic form on barley and spring wheat throughout the central and eastern portion of the Corn Belt. In addition, local epidemics of the disease occurred on oats, causing reductions in yield as well as in quality of grain. The losses sustained as well as the area damaged by the disease were similar to those of the previous epidemic season of 1919 (fig. 1), with the exception that more damage was done to the barley crop during the season of 1928. The losses were severe, especially where spring-wheat and barley varieties were grown farther south than their general geographic range of adaptation.

DISTRIBUTION OF SPRING BARLEY

The distribution of the spring-barley acreage was abnormal in 1928. The eastern and central United States, the northern or Great

Lakes section, the upper Mississippi Valley, and the northern Great Plains area are best adapted to the growing of spring barley. A large acreage of winter wheat was killed by the severe open winter of 1927–28. Barley was scarce and consequently high priced during the spring, and a large percentage of the winterkilled wheat acreage was sown to barley, especially in Ohio, Indiana, Illinois, Iowa, and Missouri, and to a lesser extent in Kansas and Oklahoma. The spring-wheat acreage also was increased in this area. The varieties used in both of these crops were not generally adapted to the central and southern portion of the Corn Belt, and furthermore they blossomed and matured during a period of humid weather. This made them especially susceptible to the scab disease.

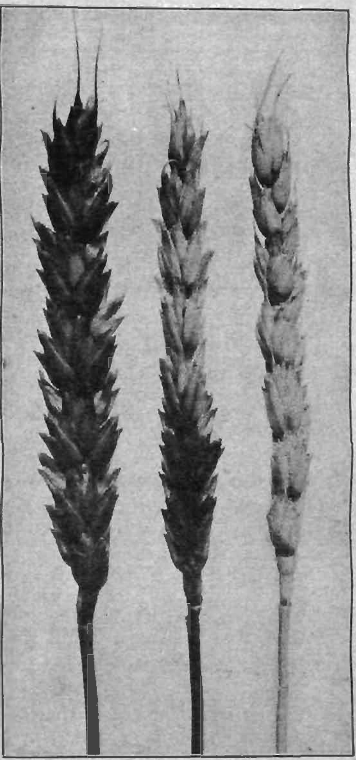

FIGURE 2.—The scab may kill only a single spikelet or part of the head (center), or the entire wheat head (right). Compare with the healthy head at the left

DESCRIPTION OF THE DISEASE

On small grains the scab disease develops on the heads during and following blossoming and also occurs on the grain seedlings as a seedling blight.

HEAD BLIGHT

The head blight or scab becomes evident during the period from flowering to the maturation of the crop. The symptoms of the disease are similar, in general, on all of the grains. Some or all of the spikelets lose their green color, die, and turn straw colored. (Fig. 2.) Barley kernels frequently turn brown, especially toward

the base of the infected spikelets. (Fig. 3.) A salmon-pink or reddish-colored fluffy, dustlike mycelium frequently is evident along the edge of the hulls or chaff and at the base of the spikelets. The extent of the spread of the disease in the head depends largely upon climatic conditions. During continued wet weather early in the blossoming period the entire head is overrun by the scab fungus, and the kernels are invaded and shrunken or destroyed. Under climatic conditions less favorable for the development of the disease, only a portion of the head or even a single spikelet may be affected.

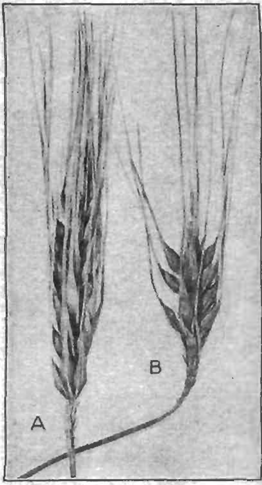

FIGURE 3.—The scab may kill parts of the barley head early (B), resulting in dwarfed heads, or it may blight part or all of the head later, causing the kernels to turn straw colored and then light brown (A)

The scabbed kernels are badly shrunken and are conspicuous by their changed surface texture and color. In wheat the scabbed grains are wrinkled and have a rough, flaky, or scabby surface, and a pale-gray or whitish to salmon-pink or reddish color. (Fig. 4.) In rye the manifestations of the disease are similar to those in wheat, except that the slightly infected rye kernels are dark brown and the badly scabbed kernels are carmine red. (Fig. 5.)

In barley and oats the disease is much less conspicuous, since the hulls cover the kernel. The infected barley hulls usually darken to light brown, especially near their bases, and have the characteristic dusty-gray color, especially on the faces of the kernels. The badly scabbed kernels are shrunken and frequently overrun by the red coating of mycelium or the scattered masses of round, black winter-spore cases. In many instances of late infection the hulls show only the darkened basal discoloration and the roughened texture and gray color on the face of the grain. The kernels within, however, show the grayish, scabby, and shriveled condition characteristic of the disease. (Figs. 6 and 7.) The hulls of the infected oat kernels are a dirty-grayish color, roughened, and frequently covered in part by the deep carmine-red mycelium or black winter-spore cases. The infected hulls are not darkened as in barley. The oat kernels within the hulls also have the light, shriveled, scabby appearance characteristic of the disease on barley. (Figs. 8 and 9.)

The scabbed, threshed grain can be detected in most cases by the presence of an occasional or many discolored kernels. The grain carrying a high percentage of infection is of light weight per bushel,

is off color, and has few or many pink or red kernels and still fewer kernels showing the scattered masses of black winter-spore cases.

The composition of the infected kernels is changed by the parasite feeding upon the stored food substances in the kernels. The stored foods of the kernels are broken down and partly used by the fungus as they are being broken down. The by-products accumulate in the kernel and remain after maturity. As compared with healthy grain, badly scabbed samples have a higher content of fatty acids and of nitrogen soluble in water and ether-alcohol. The starch content is lower, as it has been changed by the fungus to sugar. This results in a higher content of reducing sugar in the infected kernels than in the healthy grains. Likewise the breaking down and use of these stored foods by the fungus result in a higher proportion of

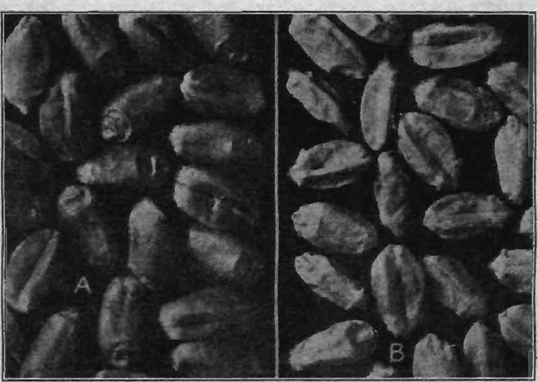

FIGURE 4.—Healthy kernels (A) and scabbed kernels (B) of Marquis wheat. Scabbed kernels are badly shriveled, gray or whitish in color, light in weight, and low in milling or feeding value

hulls and, therefore, a relatively higher crude-fiber content in infected grain.

A similar ear rot of corn is conspicuous in ear corn or shelled corn on account of the pink to red mycelium over the surface or around the embryo end of the kernel. The damage to the corn kernels is essentially similar to that in the infected kernels of the small grains.

SEEDLING BLIGHT

Seedling blight occurs either when scabbed kernels are used as seed or when poor seed or unadapted varieties are sown in infested soil. The parasite attacks the seedling during and following germination. Blighting frequently occurs before emergence of the seed-

ling, resulting in a poor stand. Other seedlings become blighted after emergence, especially before the plant reaches the tillering stage. (Fig. 10.) The infected parts below ground show a light-brown to reddish brown rot either partially or completely invading the seedling tissues. A similar wide range of symptoms occurs in the seedling blight of wheat, barley, rye, oats, and corn.

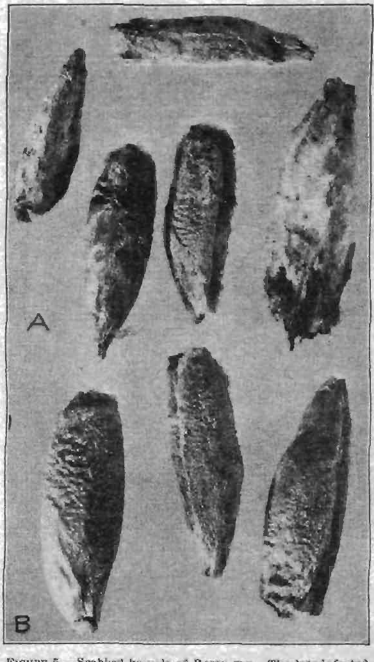

FIGURE 5.—Scabbed kernels of Rosen rye. The late-infected kernels (B) are dark colored and wrinkled. The badly infected kernels (A) are colored with a white to pink flaky growth of the fungus

CAUSE OF THE DISEASE

The head blight (scab), as well as the seedling blight of the cereals and grasses is caused by the cosmopolitan rot-producing fungus *Gibberella saubinetii* (Mont.) Sacc. It is one of the Fusarium group and in the fusarial or summer-spore stage is known as *Fusarium graminearum* Schw. In a few instances, in some sections of the United States, other closely related fungi cause the same type of disease, while in other sections and in Europe the disease is caused principally by another closely related species, *Fusarium culmorum* (W. Sm.) Sacc. In the central and eastern United States, *G. saubinetii* is responsible for about 98 per cent of the damage. This parasite has two spore stages—the summer-spore stage, called the conidial stage, and the winter-spore stage, called the perithecial stage, both of which stages are common.

The pink to red surfaces of the scabbed kernels or heads are covered with millions of summer spores or conidia. The round black

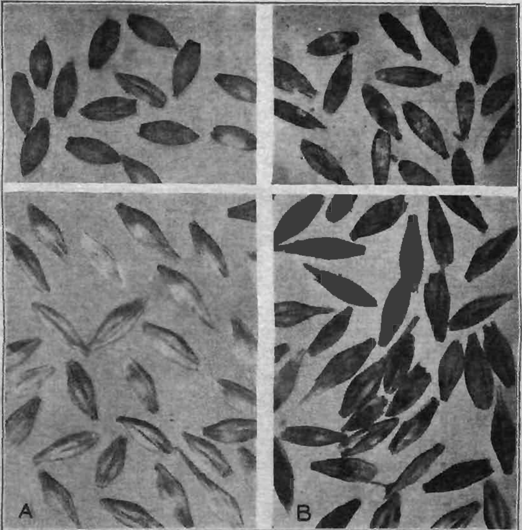

FIGURE 6.—Healthy (A) and scabbed (B) kernels of Oderbrucker barley. The scabbed kernels are light brown with a dusty-gray color over the face. The badly scabbed kernels are shrunken and frequently covered by the pink mycelium and summer spores or the black winter-spore cases. (Fig. 7.) The kernels, removed from the hulls, are grayish white or pink and shriveled

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bodies scattered over the surface of the badly infected heads and later on old straw and especially cornstalks are the winter-spore cases, or perithecia. (Figs. 11, 12, and 13.) Within these winter-spore cases the winter spores, called ascospores, are formed. These are largely responsible for the widespread wind dissemination of the parasite from old cornstalks and crop refuse to the developing grain heads during the late spring or early summer. The plowing under of old cornstalks prevents this abundant formation of winter spores.

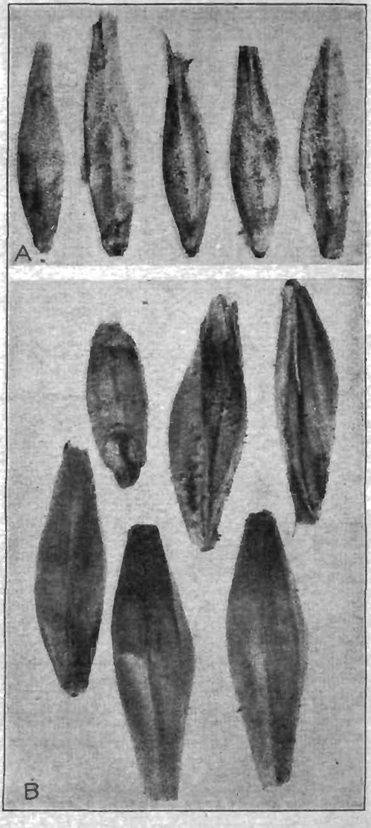

FIGURE 7.—Scabbed kernels of Oderbrucker barley, showing the range from plump but darkened (B) to gray and shriveled kernels covered by a mass of spores of the scab parasite (A)

LIFE STORY OF THE PARASITE

The life story of the scab parasite is rather complex. As stated previously, the parasite not only grows on various farm-crop plants and produces disease while they are growing, but it also lives on the straw, chaff, and cornstalks after the crop is harvested. (Figs. 12 and 13.) It grows commonly on cornstalks and straw left in a moist condition on the surface of the soil, and thus it is carried over win-

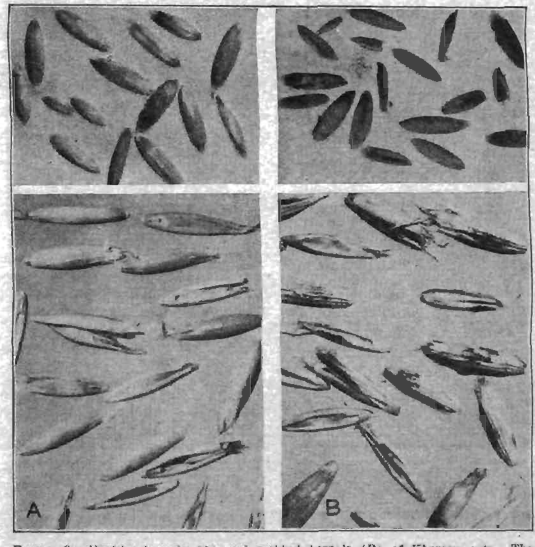

FIGURE 8.—Healthy kernels (A) and scabbed kernels (B) of Kherson oats. The scabbed kernels are dirty gray to deep carmine red. Frequently they are still inclosed in the outer chaff, bearing the round, black winter-spore cases. (Fig. 9.) The grain itself within the hull is shriveled, rough, gray to pink in color, and of poor quality and low feeding value

ter. The winter spores mature during the spring and are discharged during continued moist weather in the late spring and early summer. If they fall on moist material of almost any kind such as old straw, cornstalks, or manure, they start to grow and soon produce immense numbers of summer spores. The summer spores may also live over the winter on crop refuse. Both the summer and the winter spores are blown to the heads of grain crops, where they grow and infect the young kernel during continued moist weather. Both summer spores and winter spores may be carried over on infected kernels and sown the following season with otherwise good seed.

FIGURE 9.—Scabbed oat spikelets, showing the black winter-spore cases (perithecia) on the outside of the outer

WEATHER CONDITIONS FAVORING THE DISEASE

Weather conditions influence the development of both the scab and the seedling-blight phases of the disease. They affect the development of both the crop plants and the fungous parasite. The fungus grows best in warm, moist weather.

CONDITIONS FAVORING SCAB

Warm, rainy weather during the flowering period of the grain crop greatly favors the spread and development of scab. Spores of the parasite formed on old, moist cornstalks on the field are blown to the developing grain heads. Dry weather prevents the germination of these spores and the growth of the parasite, but warm, muggy weather, with heavy dews or quiet rains, furnishes favorable conditions for the germination of the spores and the subsequent infection and growth into the kernel. If these weather conditions prevail widely and extend over a period of time when any of the cereals are flowering or filling, a scab epidemic may spread over an entire area, as in 1919 and 1928, and cause immense losses. It is chiefly on account of variations in these conditions that the destructiveness of scab varies from year to year.

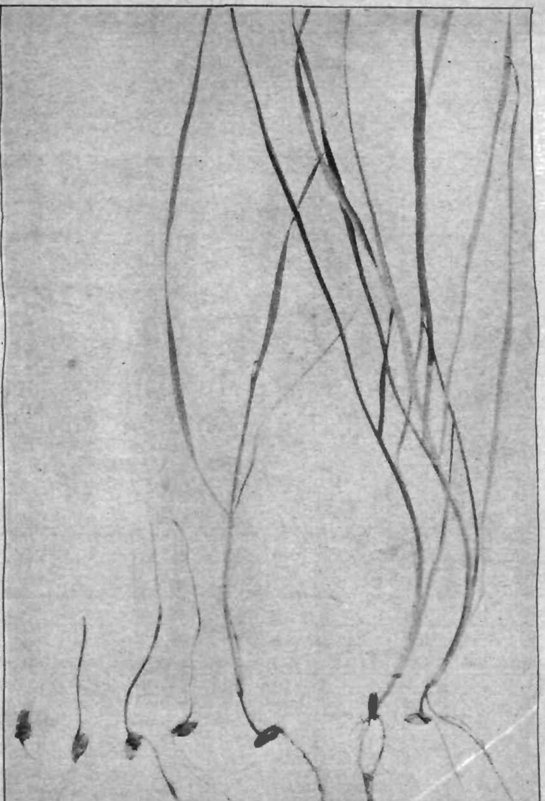

FIGURE 10.—Seedling blight caused by the scab fungus. Some of the diseased wheat seedlings fail to push out of the soil (left), others come up but die in the first-leaf stage, while others develop into weak plants (center). Normal seedlings, of the same age, from clean seed (right). Clean and treat the seed in order to control this seedling blight

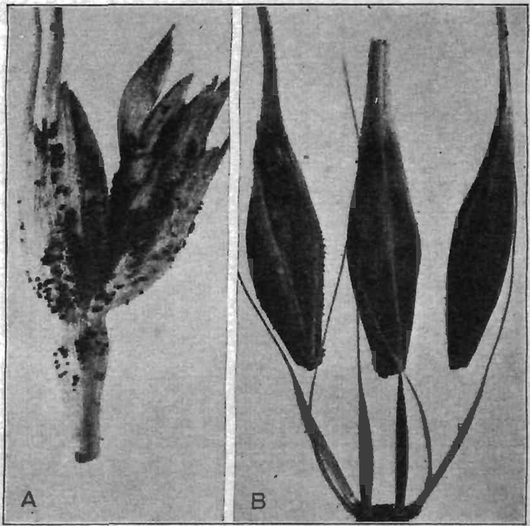

FIGURE 11.—Winter-spore cases (perithecia) of the scab fungus on part of a scabbed head of Turkey wheat (A) and of Oderbrucker barley (B). These spore cases contain the winter spores (ascospores). × 4 (approx.)

CONDITIONS FAVORING SEEDLING BLIGHT

The seedling blight develops chiefly from the scabbed kernels sown with the seed and from the parasite growing on crop refuse on the surface of the field sown. A warm, comparatively dry soil favors the development of the seedling blight on wheat, rye, and oats. A cold, dry soil favors the development of seedling blight on barley and corn. Stating it conversely, blight does the least damage under conditions favoring the seedling growth of the respective crop plants.

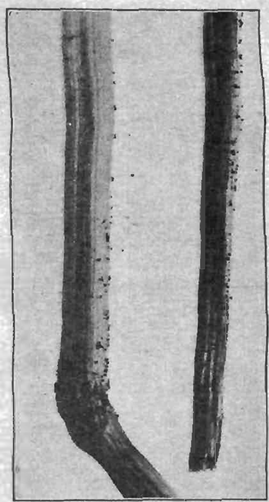

FIGURE 12.—Black winter-spore cases (perithecia) of the scab fungus on wheat straw left on the field after harvest. This material must be plowed under to prevent spread of the fungus to the next season's grain crop

CONTROL MEASURES

Under the present methods of farming in the Corn Belt, scab is very difficult to control completely. With the present quantities of cornstalks and other crop refuse left on the surface of the field after disking or poor plowing, there is an abundant development of the parasite on this crop refuse. Each year it spreads spores over the grainfields during the summer. (Figs. 12 and 13.) All that is necessary, therefore, to start an epidemic, either local or general, is moist, wet weather during or following the flowering period of the grain crops. (Fig. 14.) Obviously, cleaning up the crop refuse or plowing this material under completely, proper crop rotation, and the use of adapted varieties and of high-grade cleaned and treated seed will greatly reduce the losses from this disease. All of these methods are practicable and can be applied under general farm conditions.

FIGURE 13.—Black winter-spore cases (perithecia) on an old cornstalk (A) and corn stubble (B) taken from a wheat field near Madison, Wis. Unless all of the cornstalks and stubble are completely plowed under, these spores will spread to the flowering wheat plants during the summer and cause scab

ROTATIONS AND THE PLOWING UNDER OF CORNSTALKS

Investigations conducted during the past eight years have shown that scab is much more severe where small grains are sown on poorly prepared wheatland and cornland. (Table 1.)

TABLE 1.—*Influence of previous crop upon scab development in wheat and barley*

[T = Trace]

State	Season	Scabbed crop	Percentages of scab when crop followed—			
			Corn	Wheat	Oats	Clover
Illinois	1919	Wheat	59	33	33	22
Indiana	1919	do	39	25	16	20
Iowa	1919	do	71	49	30	
Wisconsin	1919	do	14		1	5
Do	1928	do	58	10	2	T
Do	1928	Barley	17	7	2	T

The principal damage done by scab in the northern portion of the Corn Belt has occurred where spring grains were sown on cornland on the surface of which stalks had been left lying. (Fig. 15.) Where large areas of such land are well plowed, as is practiced in the corn-borer clean-up area (fig. 16), small grains can be sown on cornland without great danger of scab losses.

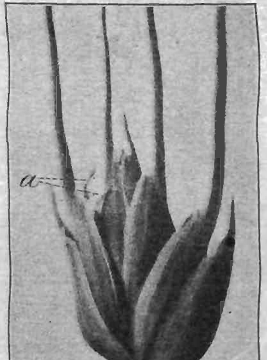

FIGURE 14.—Enlarged view of a wheat spikelet, showing the anthers (*a*) on which the scab fungus begins to grow. Later the fungus progresses downward into the flower, there to produce a scabbed kernel. Such entire spikelets or portions of heads may become blighted.

GOOD SEED, CLEANED AND TREATED

Seedling blight can be controlled by the proper selection of varieties and treatment of the seed. The varieties best adapted to the district and, if obtainable, seed free from scabbed kernels should be used. If it is necessary to use seed that contains scabbed kernels, the grain should be put through a fanning mill with a heavy wind blast to blow out the scabbed kernels and shriveled grain. After being cleaned, the seed grain should be treated with an efficient mercury dust at the rate of 2 ounces per bushel for wheat and rye and 3 ounces per bushel for barley and oats, to control the seedling blight. In treating barley it is advisable to use a dust treatment that will control the barley-stripe disease as

well as scab. Ceresan and Höchst control both of these diseases and materially reduce smut infections as well. The liquid formaldehyde, liquid copper sulphate, or hot-water treatments are not advisable, as they cause sufficient injury to the seed and seedlings to increase the damage from seedling blight when treated seed is sown in cornland or wheatland infested with the scab parasite. Seed treatment can not make dead seed germinate; therefore good seed should be selected

FIGURE 15.—Cornstalks on a field sown to winter wheat. The cornstalks were broken down with a drag, after which the field was disked and poorly plowed. Enough diseased cornstalks remain on the surface of the soil to develop an abundance of the scab fungus to infect the wheat crop very severely if there is rainy weather when the wheat is flowering. With proper plowing equipment these stalks can be turned under, and completely covered. (See fig. 16.)

at the beginning. Seed well cleaned, treated with any of the standard commercial mercury dusts, and sown in a well-prepared seed bed should make a good crop, other things being favorable.

DISEASE-RESISTANT, ADAPTED VARIETIES

Disease-resistant varieties of wheat and barley are being developed at several of the State experiment stations and Government field sta-

tions. The standard variety best adapted to the district should be used until the value of new disease-resistant varieties has been fully demonstrated. Scab-resistant spring and winter wheats of good quality are being tried each year in the area affected by the disease. Some of these have proved to be rather resistant and of good quality. Among the winter wheats were Turkey selections, Red Rock, and Minturki, and among the spring wheats, Norka, Progress, Resaca, and selections from Illinois No. 1. Illinois No. 1 is fast replacing Marquis wheat in the northern Illinois section, largely because of its resistance to scab. Likewise, Progress wheat is replacing Marquis wheat in Wisconsin and the southern portion of the spring-wheat belt, because of its resistance to scab and rust and because of its higher yields.

The breeding of barley for resistance to scab has not advanced far enough to warrant a definite statement regarding varietal resistance. In general, however, the commercial smooth-awn varieties thus far

FIGURE 16.—Clean plowing will control scab as well as the corn borer. It requires about 20 per cent more power, as well as attention to adjustments, to turn under the stalks. (Photograph from National Farm Equipment Manufacturers Association)

introduced are more susceptible than the widely grown Manchuria types, including Oderbrucker. Certain selections from smooth-awn crosses have shown resistance to barley scab during the season of 1928 and will be further selected and tested. Hooded varieties are very susceptible to scab and should be avoided where scab occurs abundantly. In general, Manchuria types of barley, including Oderbrucker, selected in and adapted to the district, usually give better yields and suffer less from scab than do newly introduced varieties.

SUMMARY OF CONTROL MEASURES

There are three essential practices for the reduction of losses from scab:

(1) Clean plowing and proper crop rotation.
(2) The use of well-cleaned and treated seed.

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